1. Explosion of Environmental Issues

1.1. From Few to Many, from Local to Global

The world science community is presently witnessing an avalanche of new environmental issues entirely different from the ones of the past decades. The issues that we were facing some 20 years ago now seem fairly simple and manageable. Sanitary conditions in urban centres have been dramatically improved by construction of sewerage systems and treatment plants; the eutrophication process has been reversed in a few water bodies. It does not mean that eutrophication is no longer a problem - it is still a predominant concern in most of the countries of the world, particularly those with a high population density, such as China, India, Russia and Eastern Europe. Nevertheless, the strategies for combatting this degenerative process are generally known: tertiary sewage treatment with phosphorus removal, ban on P-containing laundry detergents and improved agricultural practices. It is just a matter of technology and available resources to stop or reverse the process. The same applies to acidification. The most commonly known solutions, although unfortunately not always practiced are installation of scrubbers in SO_2-producing industries and compliance with emission targets, as well as the phasing-out of coal to alternative energy sources.

Since the beginning of the seventies, and particularly during the eighties, the number of new environmental issues has been growing at an alarming rate. At first, it was the widespread contamination of lake and river sediments, and the biota by mercury, as well as the wide spread pollution from other heavy metals (lead, copper, zinc, cadmium, etc.), originating from industrial discharges and emissions and frequently carried over long distances via airborne transport (A good example of this is the contamination of the Canadian Arctic from industrial sources in Russia).

Detection in the early seventies of extremely low concentrations of organic toxic contaminants from the family of chlorinated benzene compounds (PCBs, dioxins, furans, DDT derivatives and hundreds of pesticides used in agriculture and thousands of new compounds manufactured annually) was made possible only through highly sensitive and sophisticated analytical techniques. This detection has brought along unexpected "surprises": deformed fish-eating birds laying eggs with the shell too thin to hatch the off-springs, tailless turtles, feminized fish populations with degenerating male reproductive organs, fish contaminated in excess of the health limits and unsuitable for human consumption, etc. The latest stories on the impact of some chlorinated compounds that are able to mimic the female hormone estrogen on the human reproductive system are even more alarming. We are paying a high price for unwise introduction of foreign substances into our lives.

As the number of new environmental issues increased, so did their geographic extent, reaching regional and often continental proportions. The Chernobyl disaster of 1986 was a serious reminder that environmental problems and accidents are no longer a local matter that refuse to recognize international boundaries. It is now obvious that increasing frequencies of oil and other chemical spill episodes are here to stay, just like traffic accidents are prone to happen on busy expressways.

Now, almost at the turn of the century, come further surprises: potential danger of global warming through accumulation of CO_2 in the atmosphere and the resulting greenhouse effect and expected water shortages; diminished protective ozone layer of the Earth with increasing UVB radiation threatening the life on this planet; population explosion in the Third World which is already poor in food supply; uncontrolled urban sprawl in both developing and developed countries; crises in solid waste disposal; and, finally, the potential genetic impact of foreign and unknown substances on humans and their reproductive capability (low sperm count in male populations of industrialized countries, learning disorders of children raised in contaminated areas, etc.).

Figure 1 presents a summary of major environmental issues which we have faced over the past century, together with the observed response from the science community and regulatory agencies. Not only have the number of issues been growing dramatically, but their geographic extent into the whole-continent and global scale is clearly evident. Some of these issues have been with us prior to their identification by scientists such as acid rain and toxics. Most of them, such as deformities, the ozone hole or greenhouse effect, are genuinely new. The graphic pattern of the increase of new issues suggests an exponential trend, alarmingly similar to the exponential growth of the global human population. Is this a coincidence or a causal relationship? Rather, is this trend related to the recent, also exponential, developments in technology and ever increasing complexity of our life?

1.2. Science Response to the Environmental Issues

From the very beginning, emerging environmental issues have been the driving force in science development. During the twenties and forties, it was the sanitary engineers, drawing on science disciplines like hydrology and hydraulics, with the help of chemists and microbiologists, who developed a scientific base for construction of the first sewage treatment plants, ensuring substantial reduction of organic carbon and an overall improvement of dissolved oxygen conditions in receiving water bodies (primary and secondary sewage treatment processes).

The eutrophication era resulted in the integration of several scientific disciplines, such as hydrobiology, chemistry and physics, into one, known as limnology. A number of research institutes and university departments were established during this period around the world.

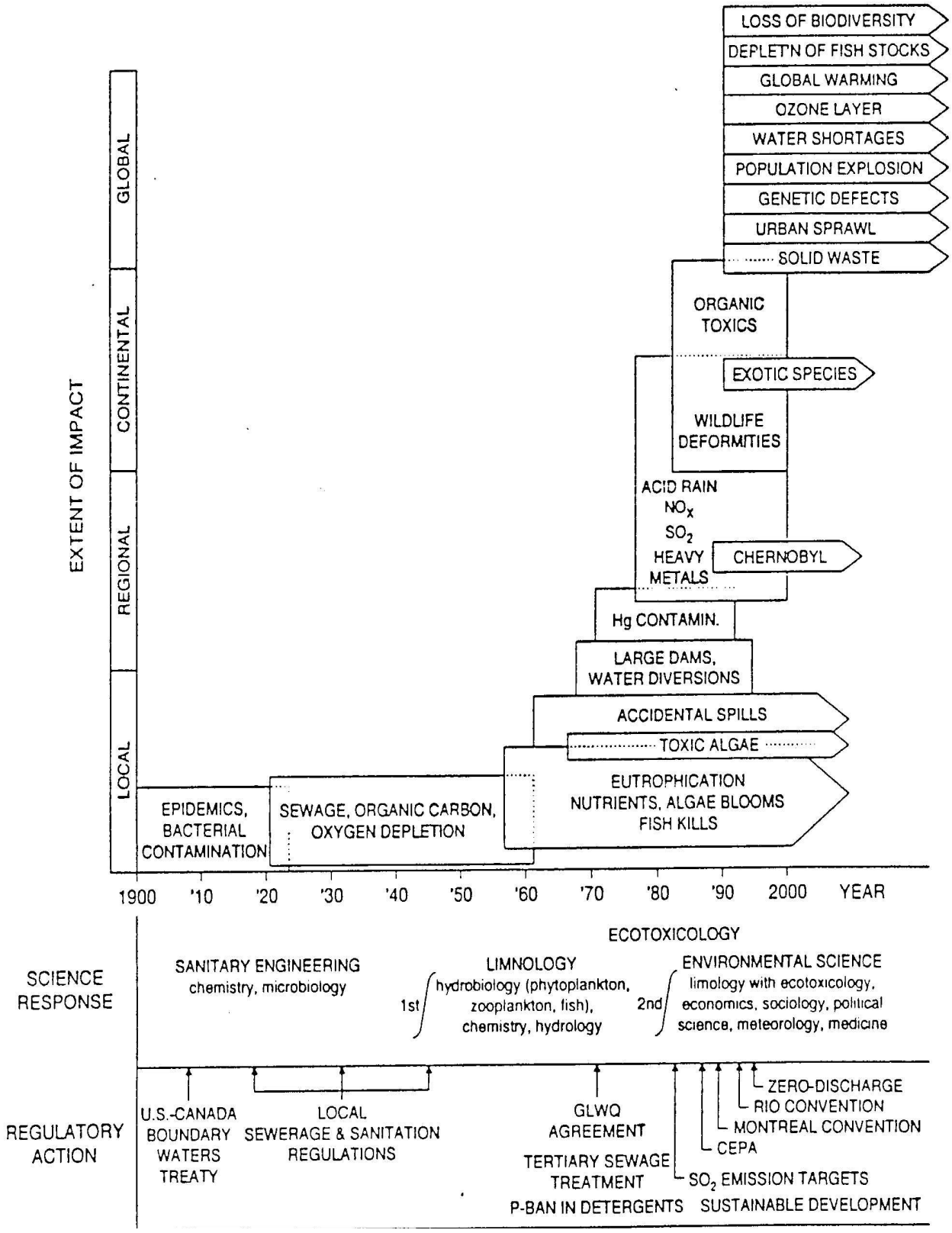

Figure 1: **Historic overview of major environmental issues over the century, with an outline of science and regulatory responses**

This period can be called the "First Integration" of aquatic disciplines into a common conglomeration with focus on quality of freshwater resources. Limnology, however, soon became incapable of solving upcoming problems of heavy metals and organic toxic contaminants. A new, specialized discipline, ecotoxicology, had to come up as a partner to address the new issue.

The concept of ecosystem approach in the early eighties expanded our traditional focus from the water to the whole basin, including human population. Later, the philosophy of sustainable development has brought economy as a partner rather than adversary into the environmental endeavour. These two new views, combined with the large-scale environmental disaster occurring around the same period, together with the first evidence of the ozone layer destruction and global warming, gave rise to the "Second Integration" of scientific disciplines into the field of environmental sciences. The creation of several new university departments or institutes followed, mainly in North America. This time, the "menu" of disciplines invited to cooperate was much larger than in the first integration, which was basically limited to natural sciences, and included non-traditional disciplines such as economics, social and political sciences, law, medicine, etc. The new issues are simply too complex to be addressed solely by natural scientists or engineers as in the past. They require a cross- and multidisciplinary approach, with active participation from the educated public, citizen groups and the media. Only close interaction of different segments of society, particularly the scientists, legislators and general public, can provide solutions and help us survive the difficult times ahead. This notion, however, does not suggest any relaxation in training and research in the highly specialized science disciplines. The integration assumes high quality individuals with world class expertise in their own field and with an ability to see the issue in its full extent (To see the whole forest, but not to ignore the individual trees).

1.3. Response of Regulatory Agencies

Response of regulatory agencies to major environmental issues as they evolved was slower than the advancement in science. This can be expected, as regulatory agencies need a solid scientific base to introduce protective or corrective action. However, with time, the action response is happening faster and faster: the Montreal Convention of 1989 to phase out CFCs met only a few years after evidence of the ozone layer problems; the Rio Convention of 1992 was even quicker in taking steps to protect biodiversity on this planet. This indicates an improvement in the rate of acceptance by legislators of environmental research results. Again, active help from the concerned public and the media is becoming imperative.

Whatever the rate of the regulatory response to new environmental issues may be - and it is likely to be faster with improved communication between science and the public, the regulatory decisions and measures must be implemented without loopholes or exceptions, and with an effective system in place to police compliance with the law. The "polluter pays" principle and a zero-discharge policy, together with personal liability and fines for plant managers where applicable, are worthy of considerations.

2. Man-Made Eco-Evolution

Warnings of growing environmental problems which could literally endanger the future of humanity appear to be causing a significant shift in attitudes among a successively increasing portion of the world's citizens. In the 1970's, the limits to development, due to resource limitation, were first brought to the attention of the public and politicians by way of the oil crises. It is clear that such limitations can change the path of development, but likely not prevent it. The concurrent phenomena of dematerialization in industrial societies, and development of new resources, are providing an alternative, but in terms of qualitative, rather than quantitative, development.

The scarcest resource, however, is our environment. Its careful and appropriate management at the world level is necessary in order to make further growth possible; at the same time, to preserve and improve the quality of life and; in the long run, to make survival for all possible. But this will not be a simple and spontaneous procedure. Rather, it will likely be the result of market pressures, individual initiatives or the force of ideas.

2.1. Phases of Eco-Evolution

The present time might be characterized as a period of imbalance and transition, rapid changes in population, economy and environment, an increasing gap between rich and poor, and an increasing disequilibria between growth and the capacity of the environment to sustain it. Until the beginning of the 19th century, the transformation of the world was a relatively slow, gradual process. Population, production and consumption of raw materials, energy, and even culture, could vary rapidly in an individual country. However, in the world as a whole, variations were slow and could be assimilated in traditional ways, and transmitted from one generation to the next.

2.1.1 ***Industrial Development:*** The rapid economic growth in Western countries during the 19th century was, first of all, characterized by a transformation process, generated by interactions between business enterprises and technology within a new political and institutional framework. This is an important observation because, focusing mainly on the increasing volume of production, enhanced productivity and expanding use of natural resources (i.e., on growth as quantitative change), can be misleading with respect not only to the dynamics of the process but also to its environmental aspects.

During an *initial phase* (1800-1900), representing the so-called Industrial Revolution, there were few, and mainly local, negative effects on the environment. These impacts were usually insignificant compared with increasing material wealth of humans, and simultaneous environmental improvements. This simultaneous improvement was no coincidence. In fact, economic growth and environmental improvements were often represented as two aspects of one and the same process.

Some examples can illustrate this progress. The agricultural revolution that occurred in many Western countries led to a steep increase in productivity and production and, at the same time, to a new and quite attractive landscape. Another example is the development of electric energy, which led to a revolutionary new means of generating motion, light and heat, and consequently gave a powerful new impetus to rapid economic growth. However, it also induced some, mainly local, damage from the production and transmission of electric power. A third example is associated with the development of water-supply and sewage systems, representing a very important degree of sanitary and environmental progress. These facilities could be constructed because of a series of innovations that also played a major role in promoting economic growth. Environmental consequences, in the form of water pollution, were, for a considerable time small, and certainly less severe than those caused by the previous lack of such systems. The recipients water bodies were, in most cases, capable of absorbing and eliminating waste materials and hazardous substances.

During the course of time, deterioration of the environment became more extensive, particularly close to manufacturing industries and urban areas. This period of an increased conflict between economic growth and environmental effects, the *second phase* of industrialization, lasted until about the mid-20th century (1900-1950). Air and water pollution became widespread in many places. However, such effects still were not dominant in too many areas. There were few serious conflicts between, on the one hand, a desire for rapid economic growth and a further increase in consumption and, on the other hand, environmental considerations. Many examples can still be found of a parallelism between growth and environmental benefits. In the industries established to this time, as well as in transportation systems, previous technical solutions were often superseded by more efficient solutions that disturbed the environment less than did their predecessors.

From about the middle of the 20th century, increasing environmental deterioration began to have not only local and regional, but in many cases much more global negative environmental implications. In many areas these negative effects outweighed the benefits of growing material wealth. This was particularly obvious when considerations included probable or possible future environmental consequences of current tendencies and trends. Examples of a close relationship between economic growth, promoted by new technology, and favourable environmental effects could still be observed, but less often than during the previous half-century. Further, environmental impacts have, in some areas, been increasing even during times when the economic growth rate was slowing down. In this *third phase* (1950-present) examples can be found in the agricultural, transportation and industrial sectors of the characteristic feature that negative environmental effects are now occurring much earlier, and are connected not only with production processes, but also with distribution and consumption, and, especially, with the handling of waste materials.

This is one reason why the long-range transport of pollutants influencing several neighbouring countries are now posing a growing problem which previously did not exist in any significant way.

This survey of historical economic and ecological development suggests there has been no single valid relationship between economic growth and environmental changes in developed countries. Thus, a closer look at this process can help to explain why the nature of environmental problems have undergone a significant change, especially since the late-19th century, with a gradual shift from mainly having beneficial, to extensive, and in many areas severe, detrimental ecological effects.

2.1.2 ***Environmental Problems****:* The character and geographic spread of environmental problems has changed over time, because environmental control efforts have successfully dealt with some of the initial problems. The magnitude of readily visible and local disturbances to the environment in developed countries has been reduced to some extent by reducing point-source pollution from the chimneys and sewers of industrial and municipal plants. On the other hand, regional and global environmental problems are increasing (Figure 2). The present pollution sources are, to a great extent, diffuse and transboundary, and can be distributed over wide areas. The effects of individual emissions are difficult to distinguish in such cases. Developing countries still suffer major local environmental problems from point sources stemming from the lack of initiation of general protection efforts.

Not only the spatial distribution but also the types of environmental problems have been expanded. A few decades ago, environmental interest in developed countries focused on water regulation, the effects of constructing water power plants and on other forms of human intervention in nature. During the late 1950's and 1960's, water pollution issues relating to discharges of plant nutrients and oxygen-consuming organic matter were primary issues. In the early 1970’s, more attention, was given to air pollution problems, especially the increasing acidification of soils and water. Further, specific pollutants, characterized by being hazardous in very small concentrations, bioaccumuable and persistent (such as DDT, PCB, mercury and other heavy metals) were in the center of public debate. The environmental concerns of the 1980's have, to a large extent, dealt with various chlorinated organic compounds emitted to air and water. During recent years, global environmental issues (e.g., global warming and depletion of the stratospheric ozone layer) have been subjected to an increasing public and political awareness.

Diffuse pollution plays an ever-increasing role. Our atmosphere is affected, e.g., by emissions from urban areas and traffic, and by extensive land use activities and livestock keeping; our soils, e.g., by peat extraction, drainage work, the application of

plant nutrients in agriculture and forestry, and deposition of air pollutants carried over long distances by wind; our waters, e.g., by stormwater drainage from urban areas, leachates from arable land and waste disposal sites, and dumping wastes at sea.

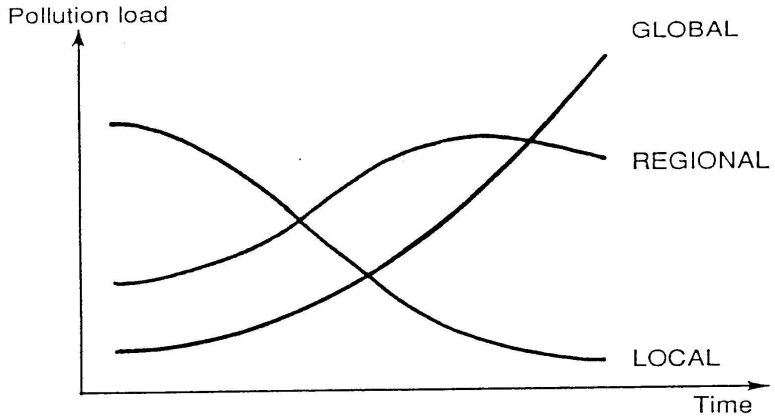

Figure 2: Outline of the changing character of the geographical spread of environmental problems

Gradually, as more environmental problems have become known, the outlook has become more complicated and, therefore, many problems have been more difficult to control (Figure 3). For example, some pollutants, acting in combination with each other, can either reinforce or reduce the effects of individual substances. Some pollutants can also affect the environment for a long time, even in very small quantities.

It is evident that, over time, environmental problems have become more complicated and complex and the link between cause and effect has become difficult to overlook. However, through continuous research and monitoring, further insights are being gained on the responses of ecological systems towards pollution inputs. The increased sophistication of analytical methods has also made it possible to detect very small amounts of specific pollutants almost anywhere on our planet.

Our increased environmental awareness also allows an enhanced awareness of small changes in the world around us. New findings have, to some extent, changed the way people judge environmental issues and the state of our environment. Many forms of environmental impact, which are unacceptable today, were considered permissible only 10 to 20 years ago.

2.1.3 ***Environmental Protection:*** Our current concept of environmental protection is partly an image of the evolution of environmental problems as described above. The work on reducing emissions to air and water from point sources started early, but has became more generally practised from 1950 on in some of the developed countries.

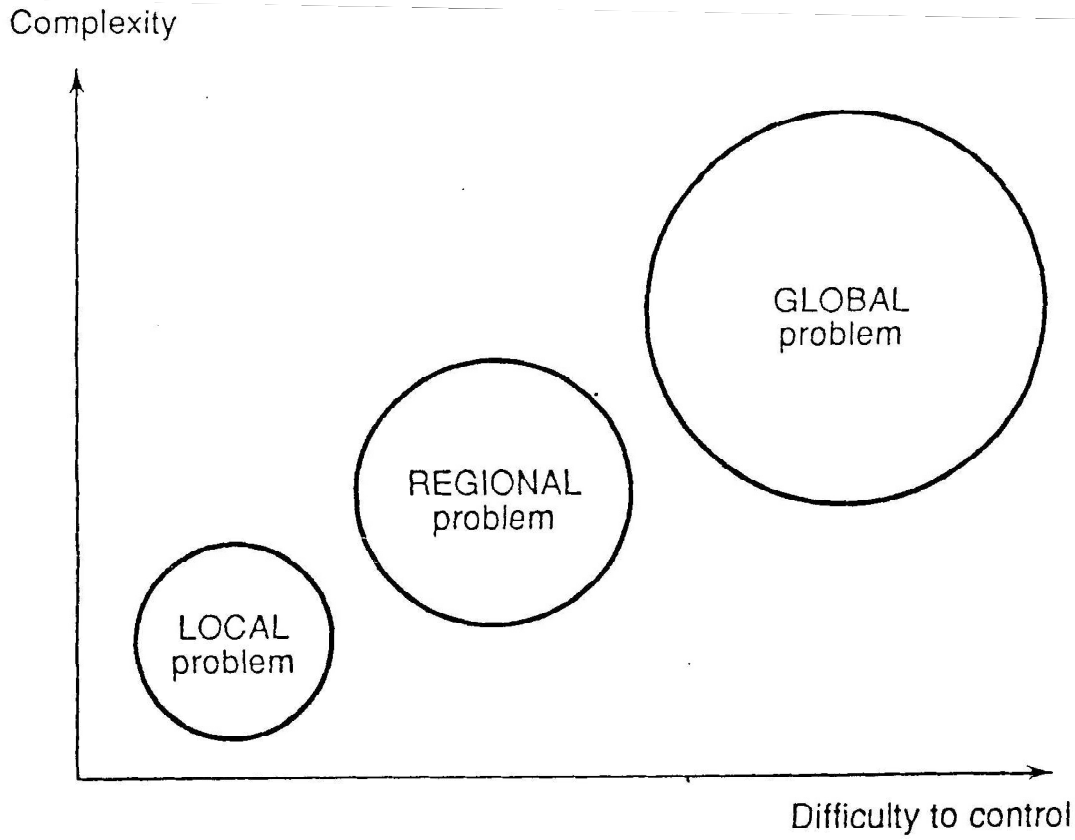

Figure 3: The emerging regional and global environmental problems, and their complexity and difficulty to control

Major progress has been made in environmental protection through administrative controls, legislation, industrial and municipal commitments and work carried out by environmental authorities.

Different approaches have been practised over the years to combat pollution of the environment. Initially, these efforts were concentrated on the gradually increasing local and clearly visible problems close to the pollution sources. An easy way to take care of a major part of the concern was to transfer the pollution away from the local area. It was generally believed that diluting pollutant discharges was an effective approach to control pollution. Higher chimneys were built, so were extensions of sewage pipes. The immediate environmental response, in terms of better local conditions, was highly appreciated by a majority of the people and it was easy for planners and decision-makers to get public and political support for introducing these types of remedial measures. However, scientists claimed that the environment in remote areas was not capable of absorbing all pollutants in the long terms, and would sooner or later suffer from the same type of problems as were faced earlier in densely populated and industrialized areas.

The technology to treat and reduce pollution from smoke stacks, and municipal and industrial sewage, made continuous progress and was gradually introduced in developed countries on a large scale during the 1960's and 1970's. This approach for

the reduction of pollution discharges is usually called an "end-of-pipe solution". By these measures, the discharges of early recognized pollutants have been reduced to a large extent in many countries. For specific pollutants, high percentage reductions, as high as 95-99 percent, have been achieved. Another positive consequence of the gradual establishment of better treatment facilities is that, coincidentally, emissions of many other substances which were unknown at the time, but to which increasing attention has been drawn in recent years (e.g., specific toxic compounds), have also been reduced to some extent. However, the purification of air and water emissions leaves a residue, in the form of ash, particles or sludge, in which pollutants are highly concentrated, thereby imposing another problem - the proper care-taking and disposal of this type of waste.

The growing environmental concern has made people more aware of the need to look at the use and conservation of natural resources in a wider aspect. The "end-of-pipe solution" did, in fact, reduce air and water emissions to a satisfactory degree but is not appropriate for good management of scarce environmental resources. A new concept of environmental protection work has emerged from these views in recent years, as it was felt necessary to look at production of goods and services "through the entire product cycle", starting from the choice of raw materials to the ultimate disposal as waste. Programmes for recovery and recycling of waste, and waste minimization, have begun to be incorporated into many companies as a production philosophy, parallel to the ongoing development of even more sophisticated treatment and purification equipment.